Results of NASA/DARPA Automatic Probe and Drogue Refueling Flight Test

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Program Objective

Phase I Objectives: (1 May 2005 - 30 August 2006)
To make one demonstration fully automatic engagement (probe plugging the drogue) between the F-18 and the Omega Air B707 tanker using the Autonomous Airborne Refueling System.

Phase II Objectives: (October 2006 - April 2007)

- Optimal Tuning of AARD Controller
- Evaluate plug performance in a turn
- Autonomous Rendezvous with the tanker
- Improve Video Tracker Performance

Technical Background

- High Risk Technology
- Technology Demonstration not Development Program
- Low Cost
- Compressed Development Schedule
- Reduced number of test conditions
- Reduced redundancy/ error correction in the system.

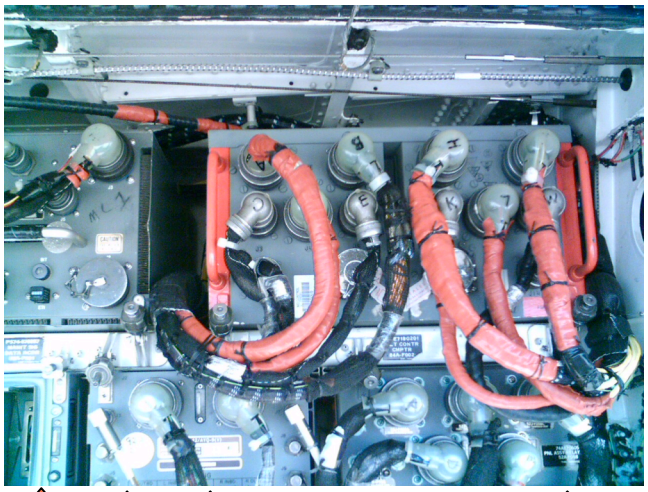
Project Timeline

- March 05 Proposal Kickoff Meeting @ DFRC
- 05-05-05 and 05-18-05 Kickoff Meetings
- 07-12-05 System Requirements Review
- 08-30-05 Preliminary Design Review
- 10-19-05 Critical Design Review
- 10-24-06 Risk Reduction Flight
- 03-02-06 Hardware Arrives at Dryden
- 04-04-06 Flight Readiness Review
- 05-18-06 Airworthiness and Flight Safety Review Board
- 06-12-06 Tech Brief (Surrogate Tanker)
- 06-16-06 through 06-29-06 Surrogate Tanker Flights
- 07-06-06 Tech Brief (Omega Tanker)
- 07-11-06 through 08-30-06 Omega Tanker Flights
- 10-1-06 Start of Phase II Flight Program
- 11-17-06 through May 2007 Phase II Flight Tests

System Architecture

Video Input

Production Support Flight Control Computers

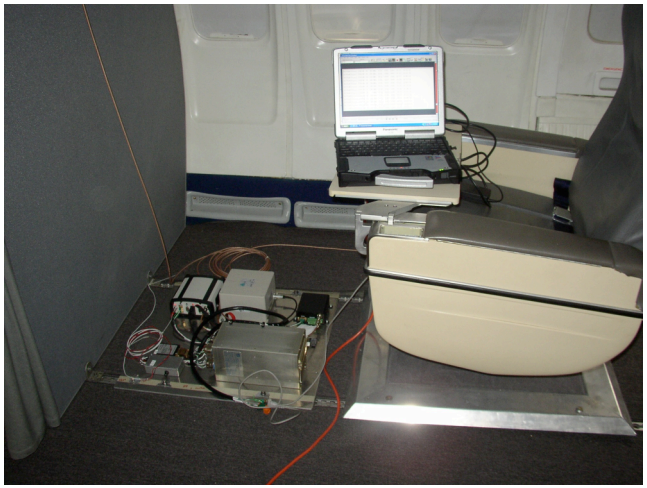


Push Button Display

Command/
Status
Information

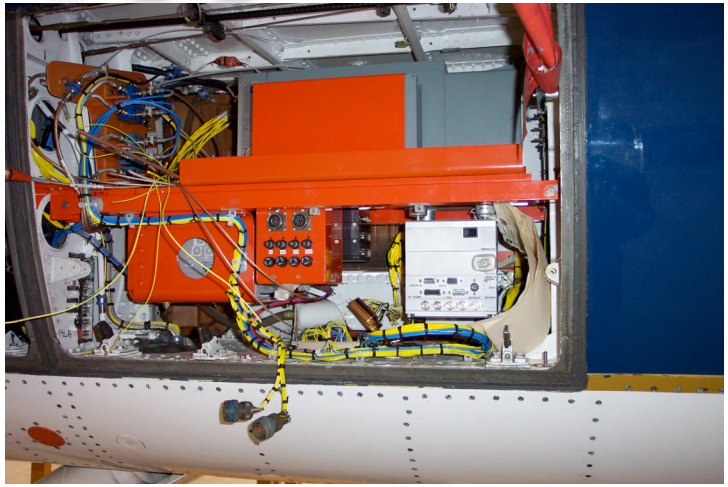
Pitch Stick
Roll Stick
Delta Throttle

Rudder =



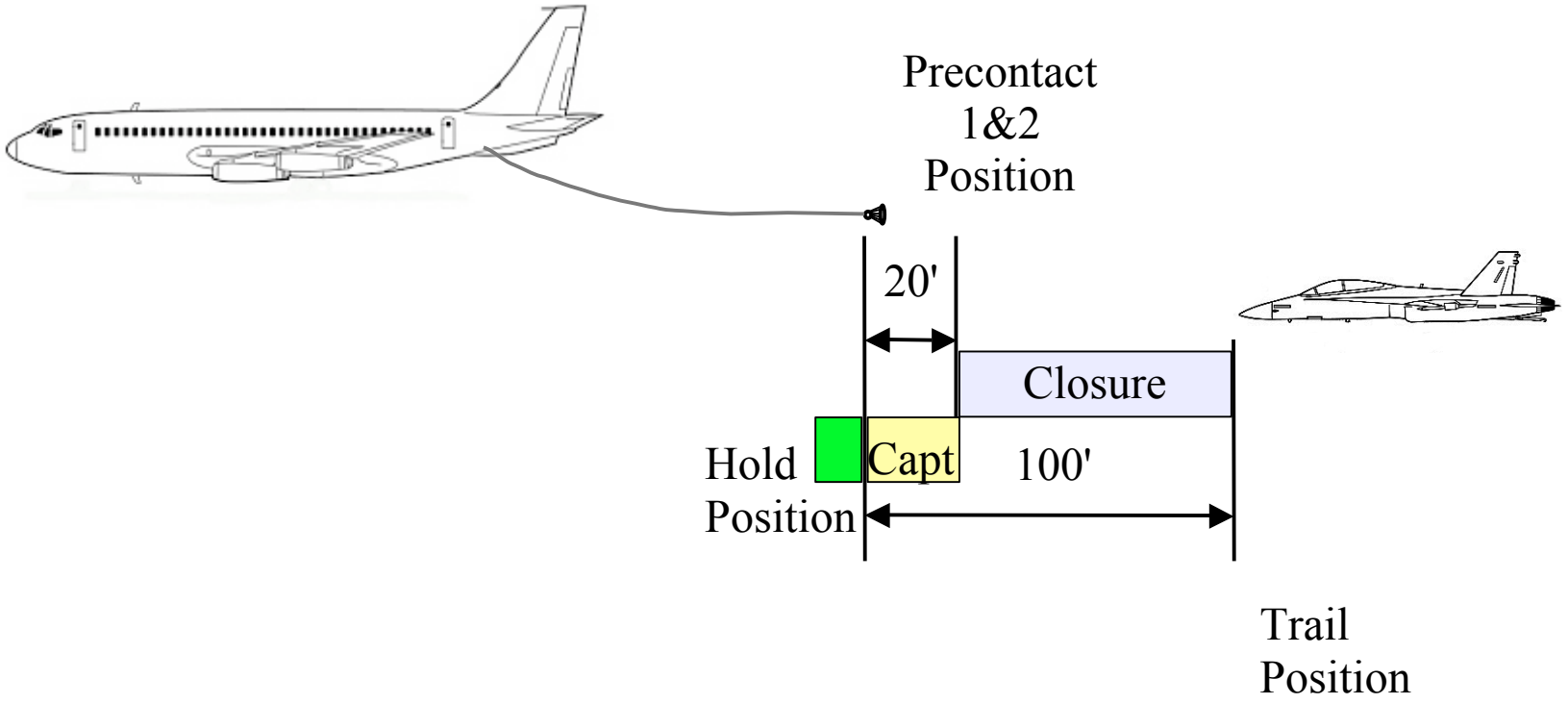
Tanker Pallet

Data Link

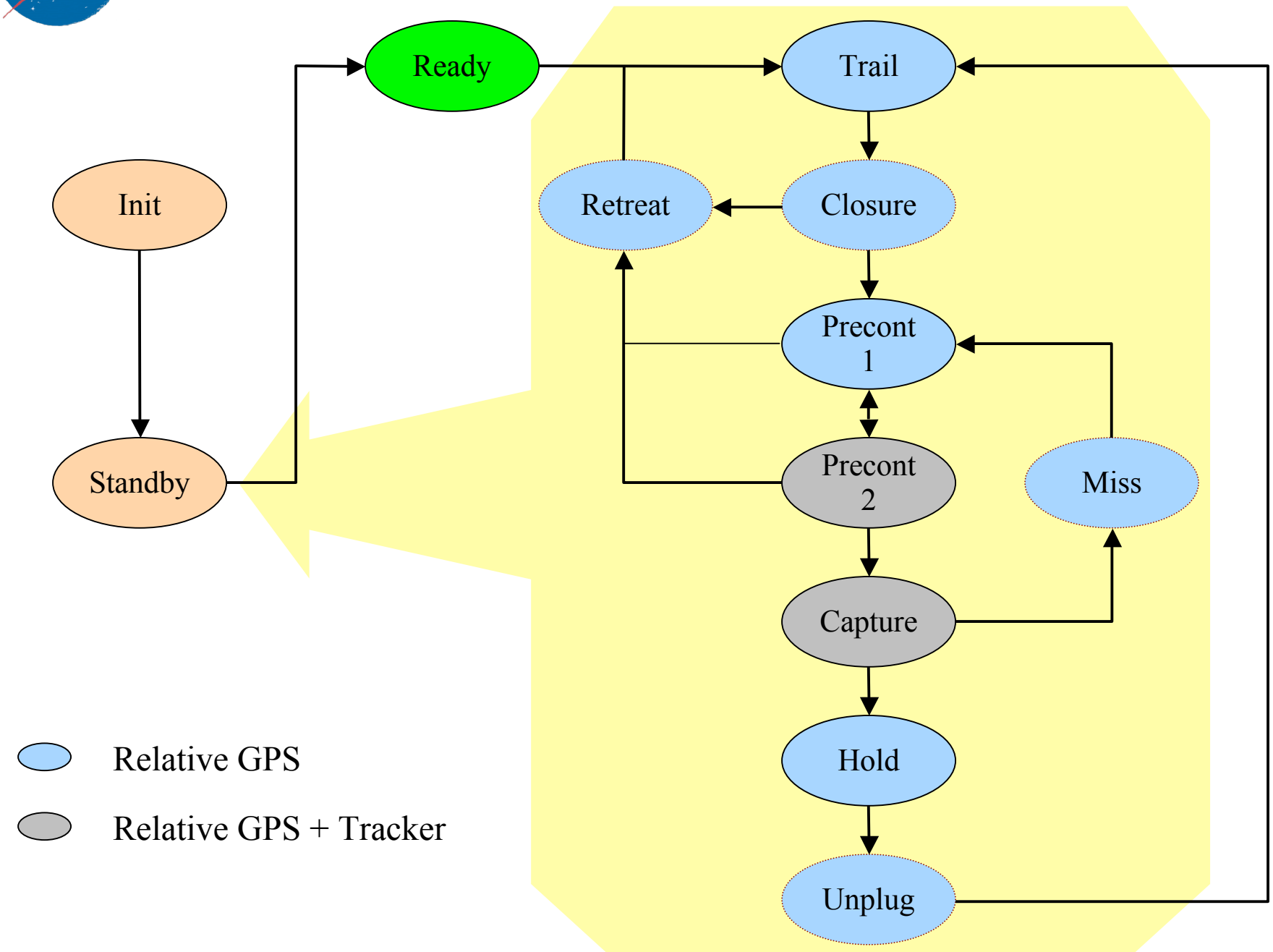


Receiver System

Refueling Geometry



AARD Modes and States



Accuracy Design Targets

- **Station Keeping Mode.**
  - ±6.5' longitudinal position
  - ±6.5' vertical position
  - ±10' lateral position
- **Capture Mode**
  - System must be able to reliably guide/control receiver aircraft within ±11” of desired location, in the conditions intended for demonstration, 95% of the time
  - Requirement driven by basket dimensions: 32” outside diameter
  - Project pilot estimates plug success rate at 95% if the probe is positioned inside 4” from outside edge of drogue

Omega Tanker Risk Reduction

- Approach to plug on left and right drogues using the cockpit and pylon camera
- Tanker pitch/ roll/ yaw maneuvers
- Varying approach rates/ trajectories
- Survey of capture and miss locations on the drogue
- Varying plug attempts at different diameters from the center of the drogue

Ground Test Activities

- Cart Testing
  - Evaluated Tanker/ Receiver subsystems and communications
  - Performed Prior to hardware delivery to Dryden
- Simulation Lab testing
  - Performed formal Verification and Validation testing of G&C algorith
  - Performed failure modes and effects testing
- Hanger Radiation Testing
  - First Integrated systems testing with a stationary aircraft
  - First evaluation of tracker performance
- Combined Systems Testing
  - Plugs out evaluation of the integrated system
  - Evaluation of tracker performance during taxi.

Combined Systems Taxi Test

Surrogate Tanker Flights

- Surrogate tanker was used to increase test efficiency
  - Lower cost per hour to fly
  - Easier to schedule.
- Tested engage/ disengage/ reversion modes.
- Commanded Autonomous modes through Precontact 1
- Gathered system performance data using sine and step inputs
- Gathered system performance data for a variety of gains
- Tracked Surrogate tanker through a turn in Trail and Precontact 1

Omega Tanker Flights

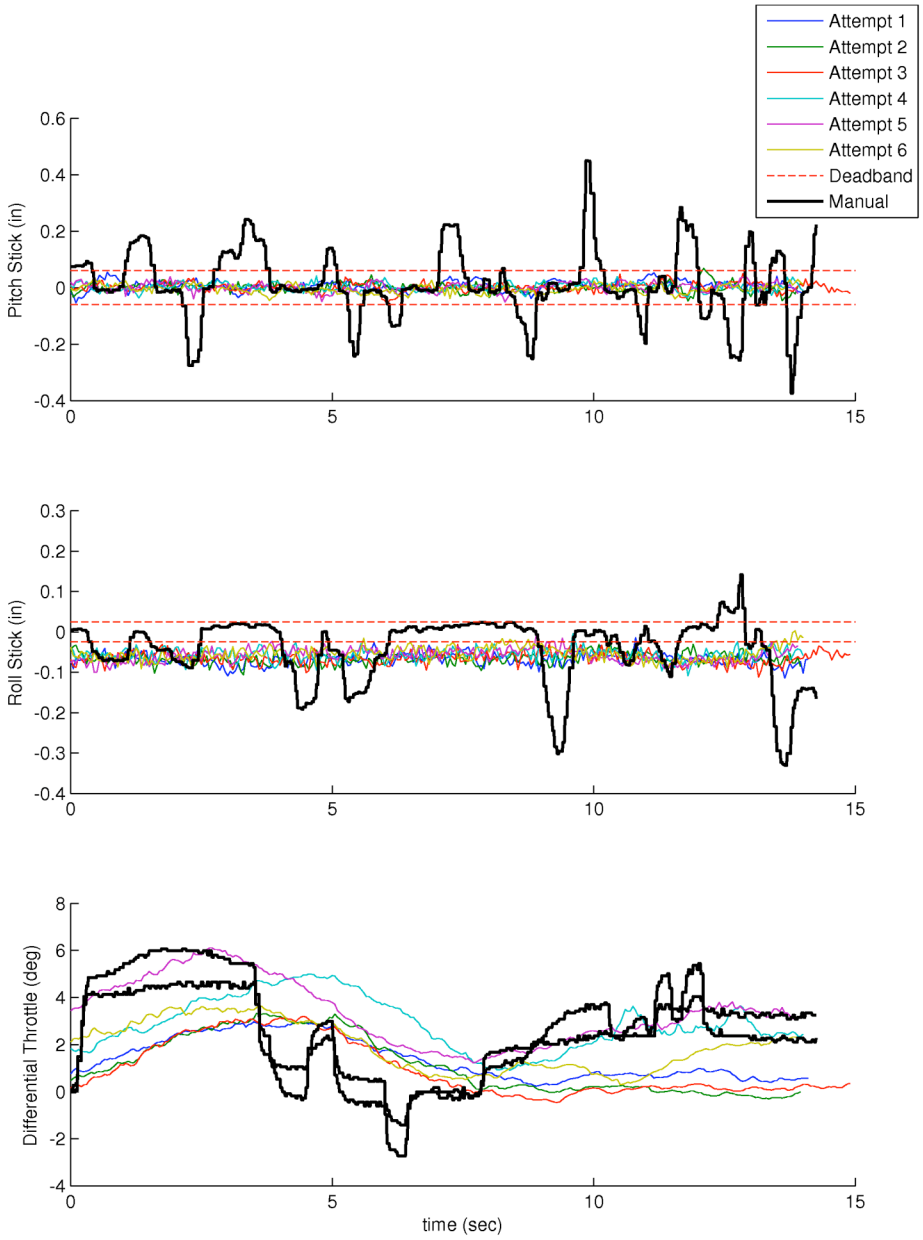
- Tested engage/ disengage/ reversion modes.
- Commanded mode transitions through unplug
- Gathered/ tuned the video tracking algorithm.

First Plug Attempt

Second Plug Attempt

Success

Control Position Comparison

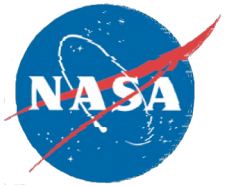


Phase II Flights

- Demonstrated Autonomous Rendezvous to Trail Position
  - 2000 ft trail, 1000 ft low, 500 ft lateral offset
  - 15 to 20 kt closure rate
- Demonstrated Autonomous Plug in a turn
  - 20 Deg Bank turn
  - Achieved a stable hold position in turn
  - Unplug in turn
- Controller and Tracker evaluation/ tuning
  - Have shown improvement in both controller and tracker performar
  - Demonstrated successful plug in mild turbulence

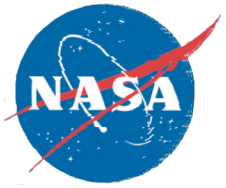
Phase II Plug Performance

Phase II Plug in a Turn



Summary

- Designed, developed and successfully tested a prototyp system to autonomously perform probe to drogue refueling.
- Demonstrated acquisition and tracking capability of the video tracking subsystem.
- Demonstrated autonomous rendezvous capability
- Demonstrated the ability to plug in a turn
- Demonstrated the ability to plug in mild turbulence



Questions?

System Architecture